Computer Science Programs

The Computer Science programs are offered through the Department of Mathematics and Computer Science. To view faculty, degree information including four year plans, please see the department page (http://bulletin.umsl.edu/artsandsciences/mathematicsandcomputerscience) in the Bulletin.

General Information

Degrees and Areas of Concentration

The Department of Mathematics and Computer Science offers undergraduate and graduate degree programs in Computer Science, a minor, and a number of certificates.

At the undergraduate level, the department offers the B.S. in computer science and the B.S. in computing technology (pending CBHE approval).

The department also offers a minor in computer science, a Certificate in Internet and Web, a Certificate in Mobile Apps and Ubiquitous Computing, a Certificate in Data Science, and, in cooperation with the Department of Information Systems, a joint Certificate in Cybersecurity.

At the graduate level, the department offers a Master of Science (M.S.) degree in computer science and a Doctor of Philosophy (Ph.D.) in mathematical and computational sciences – with a computer science option. The department also offers, in cooperation with the Department of Information Systems, a joint Graduate Certificate in Cybersecurity.

Undergraduate Programs Overview

The B.S. in computer science combines traditional computer science studies, with its depth and breadth, with more practical exposure to a wide variety of tools and technologies. Students in this program are exposed to thorough background in mathematics and statistics, and can also develop expertise in a specific area of interest through available certificates and electives, including those based on math or statistics such as AI, data science and analytics, internet-based technologies, and mobile computing.

In addition, students are prepared for working in groups, technical reading and writing, and professional and ethical aspects. Students completing this degree are well prepared for further graduate studies in computer science.

The B.S. in computing technology (pending CBHE approval) is a newer degree program that favors exposure to a wide variety of tools and technologies over traditional depth or thorough computer science background. Students completing this degree are well prepared for many careers and opportunities, determined by the choices of many available elective courses, which can still be packaged into certificates.

The Certificate in Data Science is designed to provide computing and statistical foundations for work with big data and data analytics.

The Certificate in Internet and Web is designed to provide a broad training in technologies related to the Internet and Web, with flexibility allowing a student to satisfy specific interests.

The Certificate in Mobile Apps and Ubiquitous Computing is designed to provide training in technologies and framework for mobile apps and computing.

The Certificate in Cybersecurity is designed to provide basic training in emerging areas of information, data, and network security.

Dual Programs

The Department offers a B.S./M.S. dual degree program in Computer Science for students with strong academic records. The program is designed to provide an opportunity for strong undergraduate majors to start earning graduate work credit before completing their undergraduate degree and to shorten, or accelerate, the time required to earn their graduate degrees.

Graduate Programs Overview

The M.S. degree in computer science program emphasizes practical aspects of the field. Our graduates have good understanding of the software process and its challenges, good understanding of computers systems and its parts, and be exposed to a wide range of technologies. They will also be prepared for teamwork, independent research, and technical reporting and presentations. In addition, available electives allow the students to focus in specific areas of interest.

The Ph.D. program in mathematical and computational sciences has an option in computer science. Students choosing this option will develop a breadth of abilities in the core areas of computer science at the graduate level. They will gain a depth of ability in contemporary research in their chosen subfield of Computer Science, and will be able to pursue independent research in their area of specialization.

Students may enroll in any of these graduate programs on a part-time basis, and with proper scheduling all can be completed in the evening.

Career Outlook

A degree in computer science prepares well-motivated students for interesting and fulfilling careers. Our graduates find positions in industry, government, and education. The demand for Computer Science graduates is high and it is projected to increase in the future.

Graduates in computer science from UMSL are located throughout the country, and they also have a strong local presence. They have careers in banking, health care, engineering and manufacturing, law, finance, and public service. Many are working in areas such as systems management, information systems and data management, scientific computing, and scientific positions in the armed services. Others have careers in education, especially at secondary and higher levels.

Department Scholarships

The Department of Mathematics and Computer Science offers many merit and need-based scholarships available to department majors.

The Alumni Scholarship is a monetary award for outstanding undergraduate students open to all junior and senior department majors.

The Edward Z. Andalafte Memorial Scholarship is a monetary award for outstanding undergraduate department majors at the sophomore level or higher.

The Raymond and Thelma Balbes Scholarship in Mathematics is a monetary award for students at the sophomore level or higher who are pursuing a degree in mathematics, have an overall GPA of at least 3.0 and a GPA of at least 3.2 in mathematics and who have completed three semesters of calculus.
Undergraduate Studies

General Education Requirements

All department majors must satisfy the university and appropriate school or college general education requirements (http://bulletin.umsl.edu/generaleducationrequirements). All mathematics courses may be used to meet the university’s general education breadth of study requirement in natural sciences and mathematics.

Satisfactory/Unsatisfactory Restrictions

No department majors may take mathematical sciences or related area courses on a satisfactory/unsatisfactory basis. Students considering graduate study should consult with their advisers about taking work on a satisfactory/unsatisfactory basis.

Degree Requirements

All courses of the department presented to meet the degree requirements must be completed with a grade of C- or better. At least four courses numbered 3000 or above must be taken in residence. Students must have a 2.0 grade point average in the mathematical sciences courses completed.

Students enrolling in introductory mathematics courses should check the prerequisites to determine if a satisfactory score on the Mathematics Placement Test is necessary. Placement into introductory courses assumes a mastery of two years of high school algebra.

A minimum grade of C- is required to meet the prerequisite requirement for any course except with permission of the department.

Note: Courses that are prerequisites for higher-level courses may not be taken for credit or quality points if the higher-level course has been satisfactorily completed.

Many students are qualified, as a result of having studied calculus in high school, to begin their major with MATH 1900, Analytic Geometry and Calculus II, or MATH 2000, Analytic Geometry and Calculus III. These students are urged to consult with the department before planning their programs. Credit for MATH 1800, Analytic Geometry and Calculus I, will be granted to those students who complete MATH 1900 with a grade of C- or better.

Similarly, students who are ready to begin their computer science studies with CMP SCI 2250, Programming and Data Structures, will be granted credit for CMP SCI 1250, Introduction to Computing, once they complete CMP SCI 2250 with a grade of C- or better.

Declaring the Computer Science Major

Students seeking to major in computer science are first designated as “pre-computer science majors” until they have completed CMP SCI 2750 or equivalent course. Upon successful completion of this course with a grade of C- or better, students will be allowed to declare computer science as their major. This course must be completed successfully within two attempts.

Degree Requirements in Computer Science

Candidates for the B.S. Computer Science degree must complete the following work:

1) Computer Science Core

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 1250</td>
<td>Introduction to Computing</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2250</td>
<td>Programming and Data Structures</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2261</td>
<td>Object-Oriented Programming</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2700</td>
<td>Computer Organization and Architecture</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2750</td>
<td>System Programming and Tools</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 3010</td>
<td>Web Programming</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 3130</td>
<td>Design and Analysis of Algorithms</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4250</td>
<td>Programming Languages</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4280</td>
<td>Program Translation</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4500</td>
<td>Introduction to the Software Profession</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4760</td>
<td>Operating Systems</td>
<td>3</td>
</tr>
</tbody>
</table>

2) Computer Science Electives

Select five more elective computer science courses, numbered above 3000. 15

3) Mathematics and Statistics

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1320</td>
<td>Applied Statistics I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 1800</td>
<td>Analytic Geometry and Calculus I</td>
<td>5</td>
</tr>
<tr>
<td>MATH 1900</td>
<td>Analytic Geometry and Calculus II</td>
<td>5</td>
</tr>
<tr>
<td>MATH 2450</td>
<td>Elementary Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>MATH 3000</td>
<td>Discrete Structures</td>
<td>3</td>
</tr>
</tbody>
</table>

4) Additional Skills

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGL 3130</td>
<td>Technical Writing</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours 70

There are no related area requirements for majors in Computer Science.

BS and MS Dual Degree in Computer Science

The Integrated BS/MS (“2+3”) dual degree program involves dual credit for qualified undergraduate Computer Science students. It allows the students to concurrently earn credit for some graduate courses while working on their undergraduate degree, reducing the total hours needed for the subsequent MS degree by up to 12 credit hours.

Entry Requirements

Undergraduate majors can apply for provisional admission to this program if:
1. They have completed at least 60 credit hours of coursework.
2. Their overall GPA is 3.0 or higher.
3. Non-CS majors must at the same time become CS majors.

Upon acceptance to the program in the provisional status, the student continues to work toward his/her undergraduate degree in computer science.

After completion of a minimum of 90 hours and no more than 30 hours away from the undergraduate degree, a provisionally admitted student applies for formal admission to the graduate program. At this point, the student must meet the entry requirements for admission to the M.S. degree in Computer Science.

**Degree Requirements**

After acceptance into the program, the student continues to complete his/her undergraduate degree. The student is reclassified as a graduate student from the next semester and must pay graduate fees. The student will be assigned a graduate adviser to help optimize the transition to the graduate program. The student continues taking the undergraduate courses but is also allowed to take courses reserved for graduate students. The student completes all the courses to fulfill the requirements to complete his/her M.S. degree in Computer Science – but must also complete the undergraduate requirements. Up to 12 credit hours can be counted towards both the undergraduate and graduate degrees, substantially reducing the hours needed to complete the graduate program by itself.

A student may file for and receive the undergraduate degree at any time when all the requirements are completed, before or in the same semester in which the Master's degree is completed. A student must still complete all the requirements to get a B.S. degree, regardless of whether the student files for the degree or not. A student may choose to finish the studies just with a B.S.

**Bachelor of Science in Computing Technology**

(pending CBHE approval)

Candidates for the B. S. Computing Technology degree must complete the following courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 1250</td>
<td>Introduction To Computing</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2250</td>
<td>Programming And Data Structures</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2261</td>
<td>Object-Oriented Programming</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2700</td>
<td>Computer Organization and Architecture</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2750</td>
<td>System Programming and Tools</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 3010</td>
<td>Web Programming</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4010</td>
<td>Advanced Web Development with Java</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4500</td>
<td>Introduction to the Software Profession</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4610</td>
<td>Database Management Systems</td>
<td>3</td>
</tr>
<tr>
<td>INF SYS 3844</td>
<td>Developing Business Applications In .NET</td>
<td>3</td>
</tr>
<tr>
<td>INF SYS 3868</td>
<td>Secure Software Development</td>
<td>3</td>
</tr>
</tbody>
</table>

**Computer Science Electives**

Select five more elective computer science courses, numbered above 3000

**Mathematics and Statistics**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1320</td>
<td>Introduction to Probability and Statistics</td>
<td>3</td>
</tr>
<tr>
<td>MATH 1800</td>
<td>Analytic Geometry And Calculus I</td>
<td>5</td>
</tr>
<tr>
<td>MATH 2300</td>
<td>Introduction to Discrete Structures</td>
<td>3</td>
</tr>
<tr>
<td>or MATH 3000</td>
<td>Discrete Structures</td>
<td></td>
</tr>
</tbody>
</table>

**Additional Skills**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGL 3130</td>
<td>Technical Writing</td>
<td>3</td>
</tr>
</tbody>
</table>

**Total Hours**

62

There are no related area requirements for majors in Computing Technology.

**Certificate in Data Science**

The certificate program provides basic training on skills required for working in growing and popular fields involving data and data analysis. It provides both statistical and computational background while also allowing to focus on specific technologies. A student pursuing this certificate can choose from one of the two tracks, the computational track and the statistical track. Each track consists of three required courses (9 credit hours) plus three additional elective courses (9 credit hours).

**Required Courses for the Computational Track:**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 4340</td>
<td>Introduction to Machine Learning</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4342</td>
<td>Introduction to Data Mining</td>
<td>3</td>
</tr>
<tr>
<td>Choose one from the following:</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>MATH 4005</td>
<td>Exploratory Data Analysis with R</td>
<td></td>
</tr>
<tr>
<td>MATH 4200</td>
<td>Mathematical Statistics I</td>
<td></td>
</tr>
</tbody>
</table>

**Required Courses for the Statistical Track:**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4200</td>
<td>Mathematical Statistics I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4210</td>
<td>Mathematical Statistics II</td>
<td>3</td>
</tr>
<tr>
<td>Choose one from the following:</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>MATH 4250</td>
<td>Introduction to Statistical Methods in Learning and Modeling</td>
<td></td>
</tr>
<tr>
<td>CMP SCI 4340</td>
<td>Introduction to Machine Learning</td>
<td></td>
</tr>
</tbody>
</table>

**Electives for both tracks:**

Select additional three courses from the following: 9

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 4030</td>
<td>Introduction to Intelligent Web</td>
<td></td>
</tr>
<tr>
<td>CMP SCI 4300</td>
<td>Introduction to Artificial Intelligence</td>
<td></td>
</tr>
<tr>
<td>CMP SCI 4320</td>
<td>Introduction to Evolutionary Computation</td>
<td></td>
</tr>
<tr>
<td>CMP SCI 4340</td>
<td>Introduction to Machine Learning</td>
<td></td>
</tr>
<tr>
<td>CMP SCI 4342</td>
<td>Introduction to Data Mining</td>
<td></td>
</tr>
<tr>
<td>CMP SCI 4370</td>
<td>Introduction to Biological Data Science</td>
<td></td>
</tr>
<tr>
<td>CMP SCI 4390</td>
<td>Introduction to Deep Learning</td>
<td></td>
</tr>
<tr>
<td>MATH 4005</td>
<td>Exploratory Data Analysis with R</td>
<td></td>
</tr>
<tr>
<td>MATH 4090</td>
<td>Introduction to High-dimensional Data Analysis</td>
<td></td>
</tr>
<tr>
<td>MATH 4200</td>
<td>Mathematical Statistics I</td>
<td></td>
</tr>
<tr>
<td>MATH 4210</td>
<td>Mathematical Statistics II</td>
<td></td>
</tr>
<tr>
<td>MATH 4220</td>
<td>Bayesian Statistical Methods</td>
<td></td>
</tr>
<tr>
<td>MATH 4225</td>
<td>Introduction to Statistical Computing</td>
<td></td>
</tr>
</tbody>
</table>
MATH 4250 Introduction to Statistical Methods in Learning and Modeling
MATH 4260 Introduction to Stochastic Processes

Residency requirement: of the required six courses at least five must be taken at the University of Missouri – St. Louis. Elective courses may be substituted with the permission of the program director. For more information, contact the department chair or email info@arch.umsl.edu.

Certificate in Internet and Web

The undergraduate Certificate in Internet and Web is a six-course (18 credit hours) program. It is designed to provide a broad training in technologies related to the Internet and Web, with flexibility allowing a student to satisfy specific interests. A minimum GPA of 2.5 is required for admission.

Required:
- CMP SCI 3010 Web Programming
- CMP SCI 4010 Advanced Web Development with Java
- CMP SCI 4011 Client-Side Technologies
- CMP SCI 4012 Introduction to Enterprise Web Development

Choose two of the following:
- CMP SCI 4020 Introduction to Android Apps: Android Fundamentals
- CMP SCI 4030 Introduction to Intelligent Web
- CMP SCI 4610 Database Management Systems
- CMP SCI 4730 Computer Networks and Communications
- CMP SCI 4750 Introduction to Cloud Computing
- INF SY S 3846 E-Commerce

Total Hours 18

A minimum of four courses must be taken in residence at UMSL. Courses may be substituted with the permission of the department. For more information, students can contact the department chair or email info@arch.umsl.edu.

Certificate in Mobile and Ubiquitous Computing

The undergraduate Certificate in Mobile Apps and Ubiquitous Computing is a six-course (18 credit hours) program. It is designed to provide training in technologies and framework for mobile apps and computing. A minimum GPA of 2.5 is required for admission.

Required Courses:
- CMP SCI 4020 Introduction to Android Apps: Android Fundamentals
- CMP SCI 4220 Introduction to iOS Programming and Apps
- CMP SCI 4222 iOS Apps
- CMP SCI 4792 Mobile and Ubiquitous Computing

Choose two of the following:
- CMP SCI 4010 Advanced Web Development with Java
- CMP SCI 4610 Database Management Systems

Total Hours 18

A minimum of four courses must be taken in residence in the Department of Mathematics and Computer Science at UMSL. Courses may be substituted with the permission of the department. For more information, students can contact the department chair or email info@arch.umsl.edu.

Certificate in Cybersecurity

The Undergraduate Certificate in Cybersecurity is a six-course (18 credit hours) interdisciplinary studies program. It is designed to help students from all backgrounds achieve a foundation in information security. It provides students the flexibility to focus on technical and/or managerial aspects of computer, software, network, and information security. With primary courses offered by Computer Science and Information Systems departments, the program also allows students to choose from a range of electives based on student interests. This certificate serves a broad group of managers, technical specialists, and professionals with or without a bachelor’s degree. A prior background in information security is not required to enter this program. A minimum GPA of 2.5 is required for admission.

Requirements

All students must take three required courses and three electives (at least one elective must be in Computer Science)

Required Courses
- INF SY S 3848 Introduction to Information Security
- CMP SCI 4730 Computer Networks and Communications
- or INF SY S 3842 Data Networks and Security
- CMP SCI 4782 Information Security
- or INF SY S 3858 Advanced Security and Information Systems

Electives

Choose three of the following (at least one must be a CMP SCI course):
- CMP SCI 4020 Introduction to Android Apps: Android Fundamentals
- CMP SCI 4222 iOS Apps
- CMP SCI 4700 Computer Forensics
- CMP SCI 4750 Introduction to Cloud Computing
- CMP SCI 4780 Computer and Network Security
- INF SY S 3868 Secure Software Development
- INF SY S 3878 Information Security Risk Management and Business Continuity

Total Hours 18

Students may substitute the above courses with other courses upon approval by the program adviser in either the Computer Science or Information Systems department. In all cases, 18 hours are needed to complete the Undergraduate Certificate in Cybersecurity. A minimum of four courses must be taken in residence at UMSL. Students may not receive both the Undergraduate and the Graduate Certificate in Cybersecurity.

For more information, students can contact the program directors at cybersecurityUMSL@umsl.edu.
Minor Requirements
The department offers minors in computer science, mathematics, and statistics. All courses presented for any of these minors must be completed with a grade of C- or better.

Minor in Computer Science
The requirements for the minor are:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 1250</td>
<td>Introduction To Computing</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2250</td>
<td>Programming And Data Structures</td>
<td>3</td>
</tr>
<tr>
<td>Select three additional computer science courses numbered 2000 or above</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><strong>Total Hours</strong></td>
<td></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

A minimum of two computer science courses numbered above 2000 must be taken in residence in the Department of Mathematics and Computer Science at UMSL.

Admission
Applicants must meet the general admission requirements of the Graduate School, described elsewhere in this Bulletin. Additional admission requirements for specific programs are listed below.

Master of Science in Computer Science
Candidates for the M.S. degree in Computer Science must complete 30 hours of course work, subject to the Graduate School regulations. Of these, at least 18 hours must be numbered 5000 or above, chosen with the prior approval of the Graduate Director. All courses numbered below 5000 must be completed with grades of at least B-. Outside computer science, up to 6 hours of related course work is allowed upon permission of the Graduate Director.

Students must satisfy all of the following core requirements:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 4760</td>
<td>Operating Systems</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4250</td>
<td>Programming Languages</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 5700</td>
<td>Computer Systems</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 5500</td>
<td>Software Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 5130</td>
<td>Advanced Data Structures And Algorithms</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total Hours</strong></td>
<td></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

Waiving or substituting for a specific requirement can be done on the basis of prior course work or experience at the discretion of the Graduate Director, but it will not reduce the total hours required for the degree.

Additionally, students must attend at least five different seminars or colloquium presentations in the department.

Thesis Option
Students may choose to write an M.S. thesis under the direction of a faculty member in the Department of Mathematics and Computer Science. A thesis is not, however, required for this degree. A student who wishes to write a thesis should enroll in 6 hours of CMP SCI 6900. Thesis. Students writing an M.S. thesis must defend their thesis in an oral exam administered by a committee of three department members which includes the thesis director.

Courses

**CMP SCI 1011 Introduction to the Internet and World Wide Web: 3 semester hours**
Intended for any student wishing to utilize the Internet and World Wide Web more effectively. Topics include networking basics, the Internet and World Wide Web, browsers, search engines, Web Services, utilities, tools, online privacy and security. Students will learn to develop a personal web page using skills acquired in the course.

**CMP SCI 1012 Learning to Program Using Virtual Worlds: 3 semester hours**
Introduces modern programming principles without requiring the knowledge of a traditional programming language. Instead, this course utilizes a novel graphical approach that enables the student to create, populate, and manipulate virtual 3-dimensional worlds which resemble video games. The development of these worlds allows students to gain direct experience and skills in using computers to solve problems. Students will create worlds of varying complexity.

**CMP SCI 1250 Introduction to Computing: 3 semester hours**
Prerequisites: MATH 1030 or MATH 1045 with B- or better, or MATH 1100, or MATH 1800, or a 70% on the proctored UMSL ALEKS Math Placement obtained at most one year prior to enrollment in this course. This course provides an introduction to the concepts of computation, problem solving, and computer systems. It covers fundamental programming constructs, basic data types, and modularization using a modern high level language. Problem solving skills are developed through a progression of programming projects.

**CMP SCI 2250 Programming and Data Structures: 3 semester hours**
Prerequisite: CMP SCI 1250. Continuation of CMP SCI 1250. Discusses properties and implementation of abstract data types such as lists, trees, stacks and queues. Introduces procedural and class abstraction, basic program architecture, use of interfaces, modular programming, and file processing.

**CMP SCI 2261 Object-Oriented Programming: 3 semester hours**
Prerequisite: CMP SCI 2250. Introduces object-oriented concepts, terminology, and notation (UML) using Java. Covers encapsulation, classes, objects, inheritance, and the use of class libraries. Additional topics may include graphical user interfaces, applets, and related tools and technologies.

**CMP SCI 2700 Computer Organization and Architecture: 3 semester hours**
Prerequisites: CMP SCI 1250 and CMP SCI 2250 (CMP SCI 2250 can be taken concurrently). This course introduces details of computer systems from architectural and organizational points of view. It covers data representation, basic digital logic circuits, memory types and hierarchies, I/O and storage devices, CPU architectures such as RISC, CISC, parallel, and multi-core.

**CMP SCI 2750 System Programming and Tools: 3 semester hours**
Prerequisites: CMP SCI 2250 and CMP SCI 2700 (CMP SCI 2700 can be taken concurrently). This course covers systems programming, scripting, libraries, utilities, and development tools. Additional programming topics include piping, binary files, exception handling, command-line arguments and symbolic debugging. This course also explores tools available in the Unix/Linux environments.
**CMPS 3780 Software Security: 3 semester hours**
Prerequisites: CMPS 2261 or concurrent enrollment. This course provides a survey of current Web technologies including markup languages (such as HTML/XHTML, CSS, XML), client side languages (such as JavaScript), server side languages (such as PERL, PHP), and Web protocols. Client-server computing projects are a course requirement.

**CMPS 3730 Design and Analysis of Algorithms: 3 semester hours**
Prerequisites: CMPS 2260, MATH 1320, and MATH 3000. This course addresses the design and analysis of fundamental algorithms in computer science. Studies basic sorting algorithms, priority queues, order statistics, search trees, and hash tables. Analysis techniques may involve time and space complexity analysis of both iterative and recursive algorithms, analysis of algorithm correctness, and amortized complexity analysis. Additional topics may include data compression, string manipulation, greedy algorithms, dynamic programming, and graph traversal.

**CMPS 3200 .NET Framework: 3 semester hours**
Prerequisites: CMPS 3010. This course introduces the .NET framework and related languages and technologies. Topics will include Visual Studio and C# for OOP and web applications. Additional topics may include ASP.NET with MVC, data access, and windows communication.

**CMPS 3410 Video Game Design and Development: 3 semester hours**
Prerequisites: CMPS 2261. This course covers major aspects of the design and development of video games, including world/level design, game UI design, game character design, game engine programming, 2D/3D modeling and rendering, game physics and animation. It is a project-based course in which students learn to apply acquired knowledge and skills to building a video game in a team environment.

**CMPS 3710 Assembly Language Programming: 3 semester hours**
Prerequisite: CMPS 2700. Explores machine architecture concepts and principles through a study of assembly language programming. Topics covered include integer and floating point arithmetic, procedures, conditional processing, strings, macros, and interfaces to high level languages. Programming projects using a commercially available assembly language will be required.

**CMPS 3760 Cyber Threats and Defense: 3 semester hours**
Prerequisites: CMPS 2250. This course provides students with the basic foundation knowledge in various cyber threats, defense methods and mechanisms. For cyber threats, the course uses an adversary model (resources, capabilities, intent, motivation, access) to cover threats such as password cracking, backdoors, trojans, viruses, wireless attacks, sniffing, spoofing, session hijacking, denial of service, DDoS, BOTs, MAC spoofing, web app attacks, zero-day exploits, and vulnerabilities that enable them. Cyber threat topics include attack timing, social engineering, attack indication, attack trees, insider problem, covert channels, and threat information sources (e.g., CERT). Typical cyber defense mechanisms will also be covered including intrusion detection, honeypot and honeynets, network monitoring and traffic analysis, access control, DMZ and proxies, network hardening.

**CMPS 3780 Software Security: 3 semester hours**
Prerequisites: CMPS 2261, CMPS 2750, and CMPS 3010. This course introduces the basic software security principles and pitfalls, including topics such as buffer, integer, and string problems, runtime errors, SQL and command injection. Additional topics may include data protection, secure file access, password and network security.

**CMPS 3990 Undergraduate Internship in Computer Science: 3 semester hours**
Prerequisites: Consent of Advisor. The internship provides for a student to attain field experience in an organization related to Computer Science. A student is engaged off-campus for an assignment of at least 320 hours working on a project as directed by his/her supervisor in the host organization. The project should be approved by the student's academic advisor, or a designated faculty member, who will monitor the student's progress. The course cannot be repeated for credit.

**CMPS 4010 Advanced Web Development with Java: 3 semester hours**
Prerequisites: CMPS 2261 and CMPS 3010; or graduate standing. This course covers more advanced Java topics, along with related concepts and technologies for Web development. Topics may include database connectivity, multi threading, security, networking, MVC pattern, testing and source control for Java applications, and server-side topics such as servlets and web servers.

**CMPS 4011 Client-Side Technologies: 3 semester hours**
Prerequisites: CMPS 3010. This course explores in depth the current state-of-the-art front-end, client-side technologies, focusing on JavaScript. Topics may include MongoDB, AngularJS, React, jQuery, Node.js, Express.js, and CSS.

**CMPS 4012 Introduction to Enterprise Web Development: 3 semester hours**
Prerequisites: CMPS 4010. This course covers design and implementation issues for enterprise web development, and some popular advanced technologies. Topics include MVC and persistence frameworks, such as Spring and Hibernate. Other topics may include Java Web services, EJB, messaging standards such as JMS, and Java EE design patterns. Students will develop enterprise-level web application projects. Credit cannot be earned for both CMPS 4012 and CMPS 5012.

**CMPS 4020 Introduction to Android Apps: Android Fundamentals: 3 semester hours**
Prerequisites: CMPS 4010, or consent of the instructor. This course covers the fundamental programming principles, software architecture and user experience considerations underlying handheld software applications and their development environments. Involves in-depth, hands-on examples, implemented on the Android Platform, and discussion of security. Credit not granted for both CMPS 4020 and CMPS 5020.

**CMPS 4030 Introduction to Intelligent Web: 3 semester hours**
Prerequisites: CMPS 3010 and CMPS 3130. This course covers the application of artificial intelligence and other modern techniques to help construct, navigate, and experience the Web. Topics may include retrieval models, classification, mining, association, topology, and indexing algorithms such as PageRank and HITS. Credit cannot be earned for both CMPS 4030 and CMPS 5030.

**CMPS 4140 Theory of Computation: 3 semester hours**
Prerequisites: CMPS 3130 or graduate standing. This course provides an introduction to the theory of computation. It describes basic computational models, such as finite state machines, pushdown automata, Turing machines and grammars. It also covers the concept of nondeterministic computation and the relationships between different computational models. Additionally it discusses decidability, reducibility, and classification of problems into complexity classes based on their time and space complexity, such as P, NP, and PSPACE.
**Computer Science Programs**

**CMP SCI 4220 Introduction to iOS Programming and Apps: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 2750; or graduate standing. This course will use Swift for building iOS apps. It also introduces Xcode, Interface Builder, basic design patterns like MVC and delegation, and core libraries for Swift and iOS. Additional topics may include network communication, data persistence, basic animation, and mapping. This is a project-oriented class that will require significant use of a Mac with Xcode installed.

**CMP SCI 4222 IOS Apps: 3 semester hours**
Prerequisites: CMP SCI 4220 or consent of the instructor. This course focuses on building more sophisticated iOS apps. May include networking such as web services, Bluetooth and wifi connectivity, graphics and animation in 2-d and 3-d, autolayouts, OpenGL, advanced data sources such as plist and core data, source control and unit testing. May also discuss security topics. Credit not granted for both CMP SCI 4222 and CMP SCI 5222.

**CMP SCI 4250 Programming Languages: 3 semester hours**
Prerequisites: CMP SCI 2261 or graduate standing. This course studies the principles, approaches, and trade-offs in modern programming languages, including a comparative study of syntax, semantics, and pragmatics. It also examines major programming paradigms: object-oriented, imperative, functional and logic.

**CMP SCI 4280 Program Translation: 3 semester hours**
Prerequisites: CMP SCI 2700, CMP SCI 2750, CMP SCI 3130, and CMP SCI 4250, or graduate standing. This course focuses on methods, techniques, and mechanisms used to create the abstraction from high level programming to machine level execution. Using program translation as an example of a complex task, this course also teaches how to manage and develop solutions for complex programming problems using modular incremental development and testing using an individual semester long project.

**CMP SCI 4300 Introduction to Artificial Intelligence: 3 semester hours**
Prerequisites: CMP SCI 3130. This course provides an introduction to artificial intelligence. The list of topics may include search, planning, knowledge-based reasoning, probabilistic inference, machine learning, natural language processing, and practical applications. Credit cannot be granted for both CMP SCI 4300 and CMP SCI 5300.

**CMP SCI 4320 Introduction to Evolutionary Computation: 3 semester hours**
Prerequisites: CMP SCI 2261, CMP SCI 2750 and CMP SCI 3130. This course introduces the concepts of nature-inspired problem solving with artificial evolution using selection, crossover, mutation and inheritance. It discusses applications of evolutionary algorithms, overviews the existing models and instances, and analyzes specific instances such as genetic algorithms, evolutionary programming, evolution strategies, and genetic programming. Credit not granted for both CMP SCI 4320 and CMP SCI 5320.

**CMP SCI 4340 Introduction to Machine Learning: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course provides an introduction to machine learning in the context of applications such as data mining, natural language processing, and adaptive computer systems. The course reviews several supervised, unsupervised, and reinforcement machine learning techniques such as naive Bayes networks, clustering, and decision trees. Selected concepts in computational learning theory may also be covered. Credit cannot be granted for both CMP SCI 4340 and CMP SCI 5340.

**CMP SCI 4342 Introduction to Data Mining: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course provides an introduction to data mining principles, algorithms and applications. Topics may include data preprocessing, data transformation, similarity and dissimilarity measures, data representation, classification techniques, association analysis, cluster analysis, regression, dimension reduction, and anomaly detection. Credit not granted for both CMP SCI 4342 and CMP SCI 5342.

**CMP SCI 4370 Introduction to Biological Data Science: 3 semester hours**
Prerequisites: CMP SCI 3130 or consent of instructor. This course provides an introduction into several key areas of biological data science, with a focus upon genetic data. Relevant background topics in genetics, current issues, and a variety of available resources will be explored. Upon successful completion of this course, the student will be able to evaluate algorithms for analyzing genetic data, including assessments of sources of errors and analysis of time and space complexity; address shortcomings in existing approaches; and implement efficient and effective software for exposing information hidden in genetic data. Credit cannot be granted for both CMP SCI 4370 and CMP SCI 5370.

**CMP SCI 4390 Introduction to Deep Learning: 3 semester hours**
Prerequisites: CMP SCI 3130 or consent of instructor. This course introduces mathematical foundations for deep learning, and follows with practical applications using selected domains such as image classification or protein predictions. It also covers dense neural networks, convolutional neural networks, recurrent neural networks, and other state-of-the-art networks. Credit cannot be granted for both CMP SCI 4390 and CMP SCI 5390.

**CMP SCI 4410 Introduction to Computer Graphics: 3 semester hours**
Prerequisites: CMP SCI 2250 and MATH 2450. This course covers the theoretical foundation and algorithms for computer graphics. Students learn the basics of graphics programming for modeling, rendering, and animation of 2D and 3D objects, using standard graphics APIs. A brief discussion of special graphics hardware, such as GPU, may be included. Credit cannot be granted for both CMP SCI 4410 and CMP SCI 5410.

**CMP SCI 4420 Introduction to Digital Image Processing: 3 semester hours**
Prerequisites: MATH 1900, MATH 2450, CMP SCI 2750, and CMP SCI 3130. This course focuses on image analysis and visual perception. Students learn data structures and algorithms for image processing, region and texture analysis, image filtering, edge detection, contour following, and image enhancement in both spatial and frequency domain. Other topics may include color processing, coding for storage, retrieval, transmission, and image restoration. Credit cannot be granted for both CMP SCI 4420 and CMP SCI 5420.

**CMP SCI 4500 Introduction to the Software Profession: 3 semester hours**
Prerequisites: CMP SCI 2261, CMP SCI 3010, and MATH 3000. This course focuses on software development and on the skills required for success in the software profession. Topics related to software development may include software process, models and views, software architectures, documentation, and testing strategies. Topics related to the profession may include ethics, licensing, copyright, trademarks, and professional conduct. Individual and group projects, research, and presentations may be required in this capstone course.
**CMP SCI 4520 Introduction to Object-Oriented Analysis and Design: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course covers object-oriented development, using UML and following an agile process. It discusses elements of analysis, requirements, design, implementation and deployment, such as use cases, static and dynamic models, patterns, and frameworks. This course includes a semester long project. Credit not granted for both CMP SCI 4520 and CMP SCI 5520.

**CMP SCI 4610 Database Management Systems: 3 semester hours**
Prerequisites: CMP SCI 2750 and MATH 3000, or graduate standing. This course focuses on database theory and applications, with emphasis on the relational model. Topics include database design, modeling, file systems, indexing, integrity constraints, relational algebra, normalization, transaction processing, and concurrency control. Students are exposed to emerging DBMS technologies and applications. Several programming projects will be required using a popular SQL server.

**CMP SCI 4700 Computer Forensics: 3 semester hours**
Prerequisites: CMP SCI 2750 and CMP SCI 3010, or graduate standing. This course explores topics and methodologies for examining digital evidence, along with some principles of the investigative process. Includes memory, file system, operating system, network, and mobile device forensics. This course addresses both theory and hands-on aspects for conducting digital forensic examinations.

**CMP SCI 4730 Computer Networks and Communications: 3 semester hours**
Prerequisites: CMP SCI 2750 and MATH 1320, or graduate standing. This course provides a broad overview of computer networks and communications. Covers the fundamental principles and protocols across the whole layering structure of the Internet protocol stack. A top-down approach covers multiple topics including network application layer, transport layer, network layer, link layer, and physical layer protocols. May also include a range of related technologies such as WWW, HTTP, FTP, DNS, SMTP, TCP, UDP, ICMP, IPv4, IPv6, OSPF, RIP, BGP, IEEE 802.11 (WiFi), cellular networks, LANs, Ethernet, CSMA/CD, CDMA, multimedia networking, network management, and security in Internet.

**CMP SCI 4732 Introduction to Cryptography for Computer Security: 3 semester hours**
Prerequisites: MATH 3000 or consent of instructor. This course provides an introduction to cryptography as it applies to computer security. It describes cryptographic code-making and code-breaking, and how they are integrated within larger security systems. Topics include symmetric encryption algorithms like AES, asymmetric encryption using prime number factorization and elliptic curves, message authentication codes, key exchange protocols and attacks on all these systems. Additional topics may include onion networks and blockchain technology, as well as possible attacks on those systems. Credit cannot be granted for more than one of CMP SCI 4732, CMP SCI 4780, and CMP SCI 5732.

**CMP SCI 4740 Introduction to High Performance Computing: 3 semester hours**
Prerequisites: CMP SCI 2750 and CMP SCI 3130. This course introduces algorithms for multiprocessor and multi-core architectures. Students learn the models of modern parallel computation and techniques to take advantage of parallel architectures for distributed and shared memory multi-processor architectures. Credit not granted for both CMP SCI 4740 and CMP SCI 5740.

**CMP SCI 4750 Introduction to Cloud Computing: 3 semester hours**
Prerequisites: CMP SCI 2750. This course provides an introduction to development and deployment of applications in the cloud space. Touches on different aspects of cloud computing such as IaaS, PaaS, and SaaS. Includes significant discussion on legal and security aspects of clouds in the marketplace. May also include public, private, and hybrid clouds, and Internet of Things. Credit not granted for both CMP SCI 4750 and CMP SCI 5750.

**CMP SCI 4760 Operating Systems: 3 semester hours**
Prerequisites: CMP SCI 2750 and CMP SCI 3130, or graduate standing. This course covers the structure of a generic operating system, considering in detail the algorithms for interprocess communication, process scheduling, resource management, memory management, file systems, and device management. It presents examples from contemporary operating systems and requires practical projects implemented within a modern operating system or simulator environment.

**CMP SCI 4770 Computer and Network Security: 3 semester hours**
Prerequisites: CMP SCI 4730 or graduate standing. This course provides a broad overview of computer and network security technologies and concerns from multiple perspectives, such as cryptography, Public Key Infrastructures (PKI), hashes and message digests, computer viruses and malware, email security, TCP/IP security, IPSec, Secure Socket Layer (SSL), Transport Layer Security (TLS), Virtual Private Networks (VPN), Firewall, AAA (Authentication, Authorization, Accounting), wireless and mobile systems security, secure identifications (IDs), cloud security, privacy and integrity, network attacks, system monitoring, and Intrusion Detection System (IDS). Management and human factors related to security will also be discussed.

**CMP SCI 4780 Information Security: 3 semester hours**
Prerequisites: CMP SCI 4730 or CMP SCI 4732 or CMP SCI 4780 or consent of instructor. This course covers topics related to maintaining security in an organizational infrastructure, including risk analysis of the environment, access level and control including multi-factor authentication, and detection capabilities to ensure adequate security monitoring. Additional topics may include network level protections, firewalls, intrusion detection/prevention systems, securing web and mobile applications, securing cloud implementations, and overall architectural considerations for system security. Credit not granted for both CMP SCI 4782 and CMP SCI 5782.

**CMP SCI 4792 Mobile and Ubiquitous Computing: 3 semester hours**
Prerequisites: CMP SCI 4730 or consent of instructor. This course covers mobile and wireless networking and provides a comprehensive treatment of wireless data and telecommunication networks. Topics include recent trends in mobile and wireless networking, wireless coding and modulation, wireless signal propagation, wireless local area networks, millimeter wave gigabit wireless networks, vehicular wireless networks, white spaces, Bluetooth and Bluetooth Smart, wireless personal area networks, wireless protocols for Internet of Things (IoT), and cellular networks.

**CMP SCI 4880 Individual Studies: 1-3 semester hours**
Prerequisites: Consent of instructor. This course allows a student to pursue individual studies under the supervision of a faculty member. It may include development of a software project. The course may be repeated for credit.

**CMP SCI 4890 Topics in Computer Science: 3 semester hours**
Prerequisites: Consent of the Instructor. This course covers a special topic in computer science to be determined by recent developments in the field and the interests of the instructor. This course may be taken for credit more than once so long as the topic discussed in each semester is different.
**CMP SCI 5012 Enterprise Web Development: 3 semester hours**
Prerequisites: CMP SCI 4010 or consent of instructor. Covers design and implementation issues for enterprise web development, and some popular advanced technologies. Topics include MVC and persistence frameworks, such as Spring and Hibernate. Other topics may include Java Web services, EJB, messaging standards such as JMS, and Java EE design patterns. Students will develop enterprise-level web application projects. Credit cannot be earned for both CMP SCI 4012 and CMP SCI 5012.

**CMP SCI 5020 Android Apps: Android Fundamentals: 3 semester hours**
Prerequisites: CMP SCI 4010 or consent of instructor. Covers the fundamental programming principles, software architecture and user experience considerations underlying handheld software applications and their development environments. Involves in-depth, hands-on examples, implemented on the Android Platform, and discussion of security. Credit not granted for both CMP SCI 4020 and CMP SCI 5020.

**CMP SCI 5030 Intelligent Web: 3 semester hours**
Prerequisite: Graduate standing. This course covers the application of artificial intelligence and other modern techniques to help construct, navigate, and experience the Web. Topics may include retrieval models, classification, mining, association, topology, and indexing algorithms such as PageRank and HITS. Credit cannot be earned for both CMP SCI 4030 and CMP SCI 5030.

**CMP SCI 5130 Advanced Data Structures and Algorithms: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course covers analysis of time and space complexity of iterative and recursive algorithms along with performance bounds, design of data structures for efficient performance, sorting algorithms, probabilistic algorithms, divide and conquer strategies, various algorithms on graphs, and NP completeness.

**CMP SCI 5222 Advanced iOS Apps: 3 semester hours**
Prerequisites: CMP SCI 4222 or consent of instructor. Focuses on building sophisticated apps using iOS. Will cover recent developments in networking such as web services, Bluetooth and wifi connectivity, graphics and animation in 2-d and 3-d, autolayouts, OpenGL, advanced data sources such as plist and core data, source control and unit testing. May also discuss security topics. Credit not granted for both CMP SCI 4030 and CMP SCI 5030.

**CMP SCI 5300 Artificial Intelligence: 3 semester hours**
Prerequisite: Graduate standing. This course provides an introduction to artificial intelligence. The list of topics may include search, planning, knowledge-based reasoning, probabilistic inference, machine learning, natural language processing, and practical applications. Credit cannot be granted for both CMP SCI 4300 and CMP SCI 5300.

**CMP SCI 5320 Evolutionary Computation: 3 semester hours**
Prerequisite: Graduate standing in Computer Science. This course introduces the concepts of nature-inspired problem solving with artificial evolution using selection, crossover, mutation and inheritance. It discusses applications of evolutionary algorithms, overviews the existing models and instances, and analyzes specific instances such as genetic algorithms, evolutionary programming, evolution strategies, and genetic programming. Credit not granted for both CMP SCI 4320 and CMP SCI 5320.

**CMP SCI 5340 Machine Learning: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course provides an introduction to machine learning in the context of applications such as data mining, natural language processing, and adaptive computer systems. The course reviews several supervised, unsupervised, and reinforcement machine learning techniques such as naive Bayes networks, clustering, and decision trees. Selected concepts in computational learning theory may also be covered. Credit cannot be granted for both CMP SCI 4340 and CMP SCI 5340.

**CMP SCI 5342 Data Mining: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course provides an introduction to data mining principles, algorithms and applications. Topics may include data preprocessing, data transformation, similarity and dissimilarity measures, data representation, classification techniques, association analysis, cluster analysis, regression, dimension reduction, and anomaly detection. Credit not granted for both CMP SCI 4342 and CMP SCI 5342.

**CMP SCI 5370 Biological Data Science: 3 semester hours**
Prerequisites: Graduate standing in Computer Science or consent of instructor. This course provides a introduction into several key areas of biological data science, with a focus upon genetic data. Relevant background topics in genetics, current issues, and a variety of available resources will be explored. Upon successful completion of this course, the student will be able to evaluate algorithms for analyzing genetic data, including assessments of sources of errors and analysis of time and space complexity; address shortcomings in existing approaches; and implement efficient and effective software for exposing information hidden in genetic data. Credit cannot be granted for both CMP SCI 4370 and CMP SCI 5370.

**CMP SCI 5390 Deep Learning: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course provides an introduction to deep learning. Topics include dense neural networks, convolutional neural networks, and recurrent neural networks. The course will cover building, training, and using deep neural networks for solving various machine learning problems such as image classification and protein contact prediction. Credit cannot be granted for both CMP SCI 4390 and CMP SCI 5390.

**CMP SCI 5410 Computer Graphics: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course covers the theoretical foundation and algorithms of computer graphics. Students learn the basics of graphics programming for modeling, rendering, and animation of 2D and 3D objects, using standard graphics API. A brief discussion of special graphics hardware, such as GPU, may be included. Credit cannot be granted for both CMP SCI 4410 and CMP SCI 5410.

**CMP SCI 5420 Digital Image Processing: 3 semester hours**
Prerequisites: Graduate Standing in Computer Science. This course focuses on image analysis and visual perception. Students learn data structures and algorithms for image processing, region and texture analysis, image filtering, edge detection, contour following, and image enhancement in both spatial and frequency domain. Other topics may include color processing, coding for storage, retrieval, transmission, and image restoration. Credit cannot be granted for both CMP SCI 4420 and CMP SCI 5420.
CMP SCI 5500 Software Engineering: 3 semester hours
Prerequisite: Graduate standing. Introduces software engineering as a discipline, discusses stages of the software life cycle, compares development models such as waterfall, prototyping and incremental/iterative, covers requirements analysis, effort and cost estimation, compares structured and object-oriented analysis and design methods. Discusses verification/validation, quality assurance, software reliability, testing methods, maintenance, documentation, project management and team structure, metrics, and available tools.

CMP SCI 5520 Object Oriented Analysis and Design: 3 semester hours
Prerequisite: Graduate Standing in Computer Science. This course covers object-oriented development, illustrated with a visual modeling language and following an agile process. Discusses elements of analysis, requirements, design, implementation, and deployment such as use cases, static and dynamic diagrams, patterns, and frameworks. This course includes a semester long project starting with requirements and culminating with deployment. Credit not granted for both CMP SCI 4520 and CMP SCI 5520.

CMP SCI 5620 Intelligent Information Retrieval: 3 semester hours
Prerequisites: CMP SCI 4300 or CMP SCI 5300. This course studies techniques for analysis of information by statistical, syntactical, and logical methods. Topics related to multimedia information are also discussed.

CMP SCI 5700 Computer Systems: 3 semester hours
Prerequisite: Graduate standing in Computer Science. This course focuses on parallel computing architectures, including RISC, pipelining, vector processing, SIMD, MIMD, and array processing. It introduces different memory and I/O subsystems, hardware description languages, and it demonstrates performance enhancement using different architectures studied.

CMP SCI 5732 Cryptography for Computer Security: 3 semester hours
Prerequisites: Graduate standing. This course provides an introduction to cryptography as it applies to computer security. It describes cryptographic code-making and code-breaking, and how they are integrated within larger security systems. Topics include symmetric encryption algorithms like AES, asymmetric encryption using prime number factorization and elliptic curves, message authentication codes, key exchange protocols and attacks on all these systems. Additional topics may include onion networks and blockchain technology, as well as possible attacks on those systems. Credit cannot be granted for more than one of CMP SCI 4732, CMP SCI 4780, and CMP SCI 5732.

CMP SCI 5740 High Performance Computing: 3 semester hours
Prerequisite: Graduate Standing in Computer Science. This course introduces algorithms for multiprocessor and multi-core architectures. Students learn the models of modern parallel computation and techniques to take advantage of parallel architectures for distributed and shared memory multi-processor architectures. Credit not granted for both CMP SCI 4740 and CMP SCI 5740.

CMP SCI 5750 Cloud Computing: 3 semester hours
Prerequisites: Graduate standing. Provides an introduction to development and deployment of applications in the cloud space. Touches on different aspects of cloud computing such as IaaS, PaaS, and SaaS. Includes significant discussion on legal and security aspects of clouds in the marketplace. May also include public, private, and hybrid clouds, and Internet of Things. Credit not granted for both CMP SCI 4750 and CMP SCI 5750.

CMP SCI 5782 Advanced Information Security: 3 semester hours
Prerequisites: CMP SCI 4730 or CMP SCI 4732 or CMP SCI 4780 or CMP SCI 5732 or consent of instructor. The topics covered in this course are risk analysis to understand the security requirements of an environment; access controls to understand the level of controls needed for different practical situations, including multi-factor authentication; detection capabilities, to ensure adequate security monitoring for information systems; network level protections, with firewalls, intrusion detection/prevention systems; securing the web and mobile applications and cloud implementations; and overall security architecture to understand how various controls can provide the security-in-depth that is required in the current environment. Credit not granted for both CMP SCI 4782 and CMP SCI 5782.

CMP SCI 5794 Security of IoT Systems: 3 semester hours
Prerequisites: CMP SCI 4730 or consent of the department. This course covers the cutting-edge techniques on the emerging edge cloud and wireless/mobile Internet of Things (IoT) systems. It covers the IoT reference architecture, integrated IoT security architecture, major threats and vulnerabilities with the IoT devices and edge cloud, and defense mechanisms. It includes hands-on labs on both the vulnerabilities and defense of the systems. Credit cannot be granted for both CMP SCI 4794 and CMP SCI 5794.

CMP SCI 5870 Computer Science Seminar: 1-3 semester hours
Prerequisites: Graduate standing. This is a seminar on various topics. Substantial student reading and participation is expected. It may be taken more than once for credit with the consent of the department.

CMP SCI 5880 Computer Science Independent Project: 1-3 semester hours
Prerequisites: Graduate standing and consent of instructor. This course offers the student an opportunity to work on an advisor-supervised project, individually or in a group. A student may repeat the course for up to 6 credit hours total, but at most 6 hours can be accumulated for CMP SCI 5880 and CMP SCI 6900.

CMP SCI 5890 Topics in Computer Science: 1-3 semester hours
Prerequisites: Graduate standing. This course offers various topics not offered on a regular basis. This course may be taken for credit more than once so long as the topic discussed in each semester is different.

CMP SCI 5900 Graduate Internship in Computer Science: 3 semester hours
Prerequisites: Consent of Advisor. The internship provides for a student to attain field experience in an organization related to Computer Science. A student is employed off-campus for an assignment of at least 320 hours working on a project as directed by his/her supervisor in the host organization. The project should be approved by the student's academic advisor, or a designated faculty member, who will monitor the student's progress. The student is responsible for having the project supervisor at the company establish contact with the academic advisor to establish schedule and goals, and a procedure to evaluate the goals. The student will submit a written report to the advisor at the end of internship. The course cannot be repeated for credit. Students completing this course will be allowed only up to three hours of Independent Study (CMP SCI 5880).
**CMP SCI 6320 Advances in Evolutionary Computation: 3 semester hours**
Prerequisites: CMP SCI 5320. This course focuses on some advanced topics in genetic and evolutionary computation (both theory and applications). Topics may include genetic algorithm variants, intelligent metaheuristics, evolutionary machine learning, differential evolution, swarm intelligence, learning classifier systems, and Markov models. A substantial part of the course will be based on selected topics from recent literature. This is a project-based course, with the project typically involving literature search and conducting and reporting research. Projects may involve developing specific applications or implementing a specific model.

**CMP SCI 6340 Genetic Programming: 3 semester hours**
Prerequisites: CMP SCI 5320. This course provides an in-depth exploration of Genetic programming, including advanced concepts such as scalability, evolution of modularity and regularity, and constrained evolution with CGP, STGP, or CFG-based GP. It may be reading, research, or application oriented.

**CMP SCI 6410 Topics in Computer Graphics: 3 semester hours**
Prerequisites: CMP SCI 4410 or CMP SCI 5410. This course covers various aspects of advanced graphics techniques, such as geometric modeling, rendering, shading, texturing, and computer animation. The course provides an in-depth study of recent advanced topics in computer graphics.

**CMP SCI 6420 Topics In Image Processing and Multimedia: 3 semester hours**
Prerequisites: CMP SCI 5420. This course covers new developments in digital image processing, computer vision, and multimedia. Topics to be covered may include image databases, object tracking, and large-scale data visualization.

**CMP SCI 6900 Thesis: 1-6 semester hours**
Prerequisites: Completion of at least 12 graduate credits and approval of research topic by thesis advisor. This course is designed for those students intending to present a thesis as part of their M.S. program. At most 6 hours can be accumulated for CMP SCI 5880 and CMP SCI 6900.